Detector Alignment for a Parity-Violating Asymmetry Measurement in

$$\vec{\mathbf{n}} + \mathbf{p} \rightarrow \mathbf{d} + \gamma$$

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for the NPDGamma Collaboration

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The NPDGamma Experiment at Los Alamos National Laboratory

NPDGamma is a nuclear physics experiment at LANSCE

NPDGamma is under construction and will begin data collection in 2003.

Measurement of the Parity-Violating Gamma Asymmetry A_γ in the Capture of Polarized Cold Neutrons by Para-Hydrogen, $\vec{n} + p \rightarrow d + \gamma$

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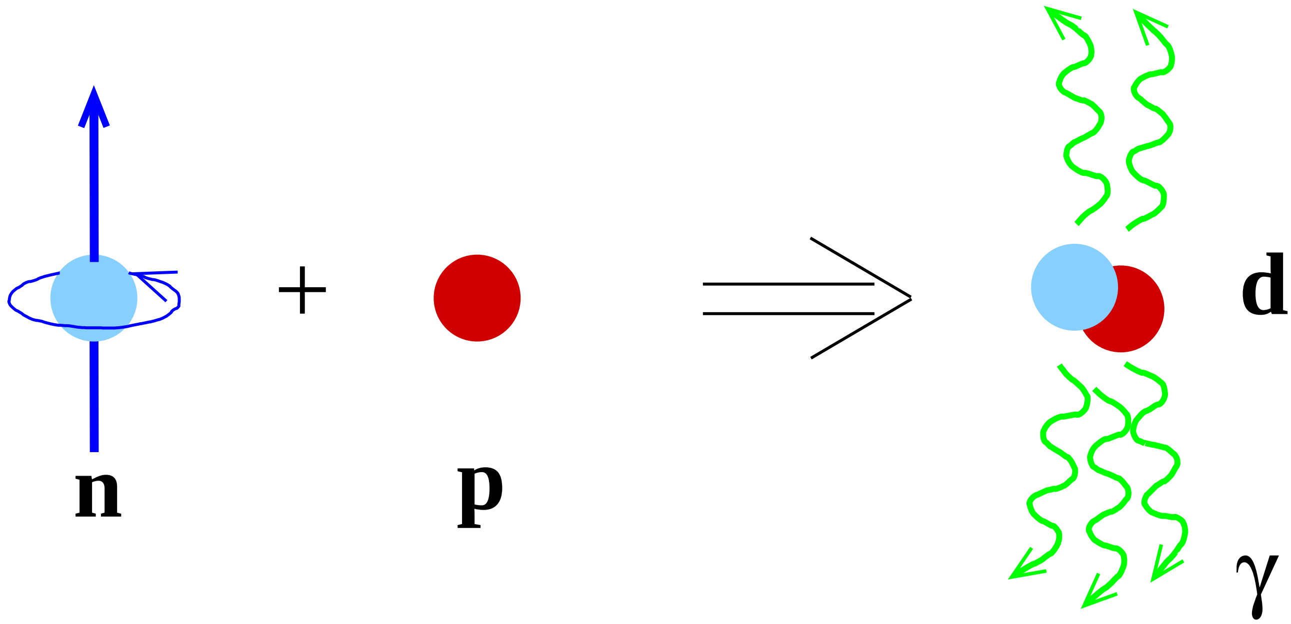
$\vec{n} + p \rightarrow d + \gamma$ (2.2 MeV)

NPDGamma will measure A_γ, the parity-violating asymmetry in the distribution of emitted γ's



If the up/down γ rates differ, parity is violated (PV $\longrightarrow$ signature of the weak interaction)

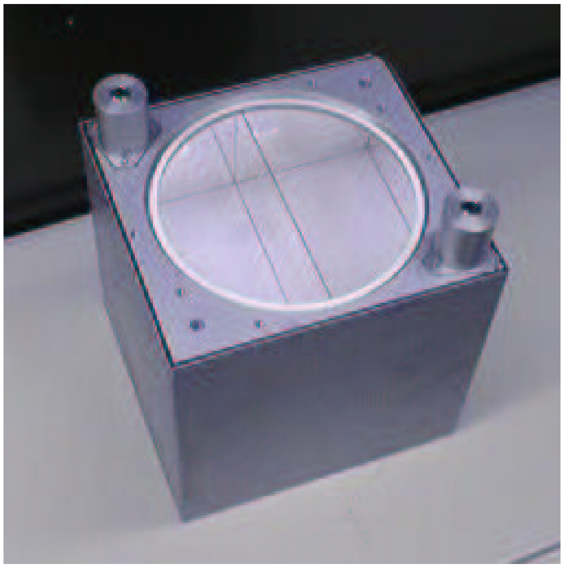
Expected asymmetry $\approx -5 \times 10^{-8}$

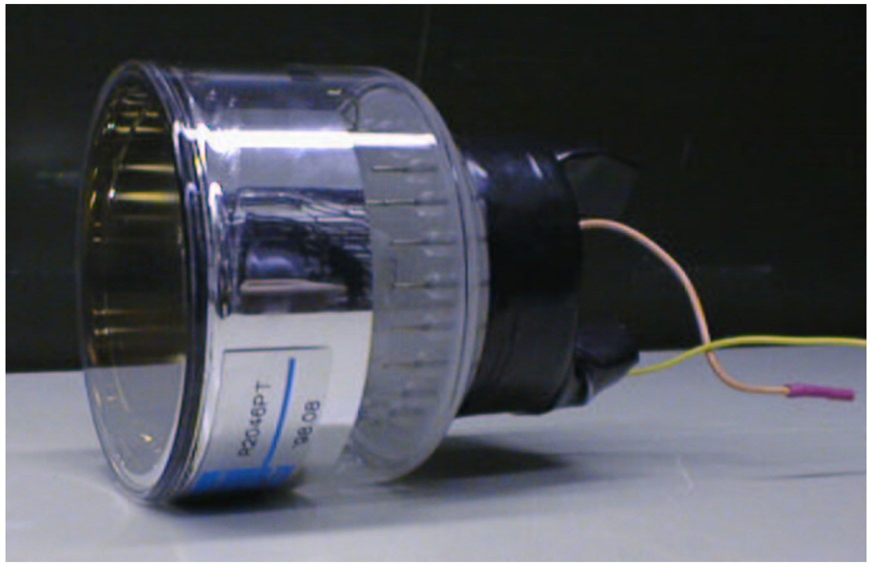
Goal experimental error: 0.5×10^{-8}

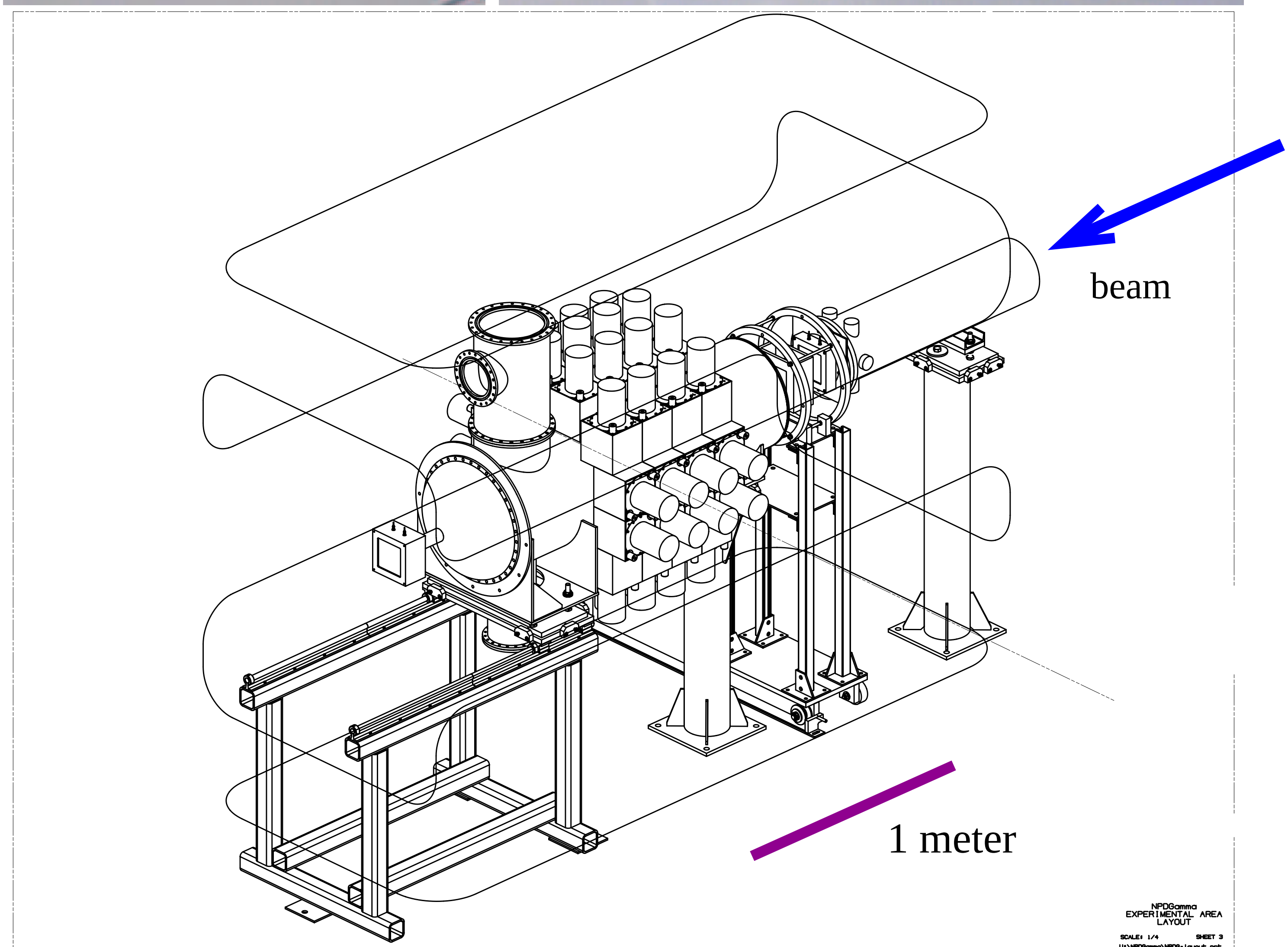
Low-energy PV N-N interaction is described by weak meson-nucleon coupling constants.
A_γ is a clean measurement of H_π^1: $A_\gamma \approx -0.045 H_\pi^1$

CsI(Tl) and Photodiode γ Detectors

48 detectors in the full array







(Neutron polarization direction up-down.)

Detector Alignment

NPDGamma will measure a very small up-down asymmetry, A_γ, which has a cosine dependence.

Left-right asymmetries will produce a false signal if the angles of the detector elements are incorrect.

Left-right asymmetries:

- Mott-Schwinger scattering
  Electromagnetic spin-orbit interaction of moving n magnetic moment and the electric field of the target nucleus.
  ($\sim 10^{-8}$ effect)

- Parity-allowed $\vec{\mathbf{n}} + \mathbf{p} \to \mathbf{d} + \gamma$ effects
  Interaction between n and p magnetic moments and interference of S and P wave amplitudes.
  ($A_\gamma^{PC} = 0.67 \times 10^{-8}$ @ 3 meV)

A. Csoto, B.F. Gibson, G.L. Payne, Phys. Rev. C**56** (1997) 631.

Alignment Requirements

Magnetic field direction determines n spin axis. (^{3}He polarization direction & spin transport.)

B field direction can be determined by flux-gate magnetometer and theodolite survey to a few mrad.

Need to know the detector angles to 20 mrad to suppress up-down contributions from 10^{-8} left-right asymmetries to the few $\times 10^{-10}$ level.

Ability to separate the up-down and left-right asymmetries can be used as a cross-check.

Possible schemes studied in test runs in Fall 2000 and Fall 2001.

Alignment Methods

Elegant

Clever

Brute Force

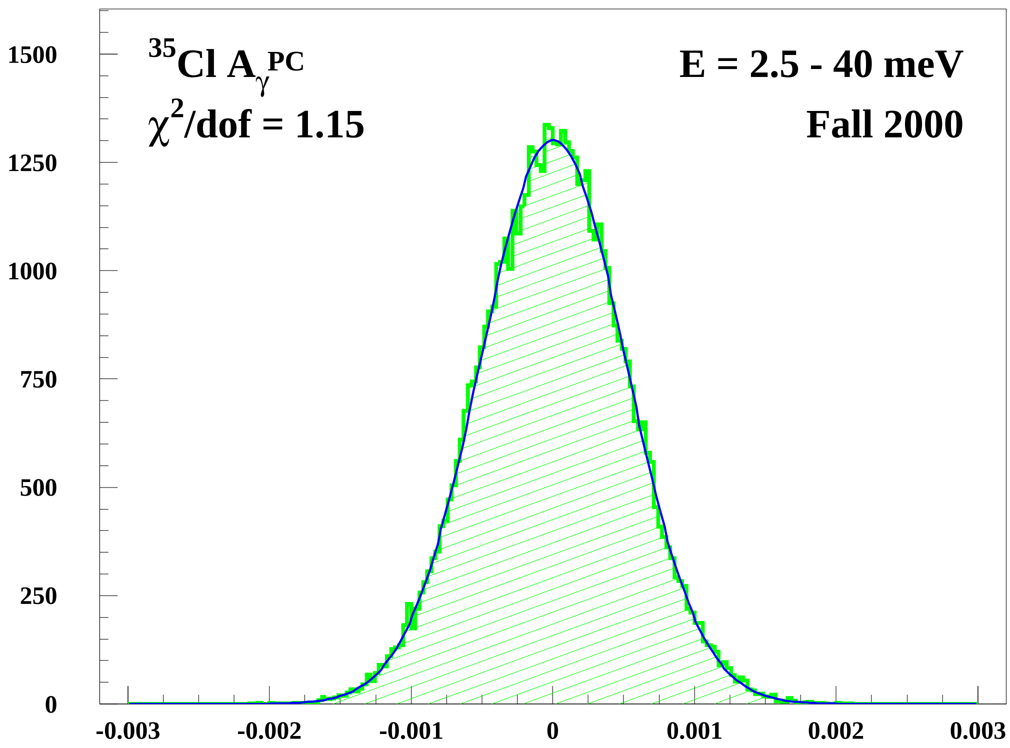
Elegant Method

Use a large physics left-right asymmetry.

Many nuclear systems exhibit 10^{-5} or larger PV asymmetry effects, possibly the same enhancement contributes to PC asymmetry?

No such luck.

PC Asymmetry Measurements on Cl, La, Cd

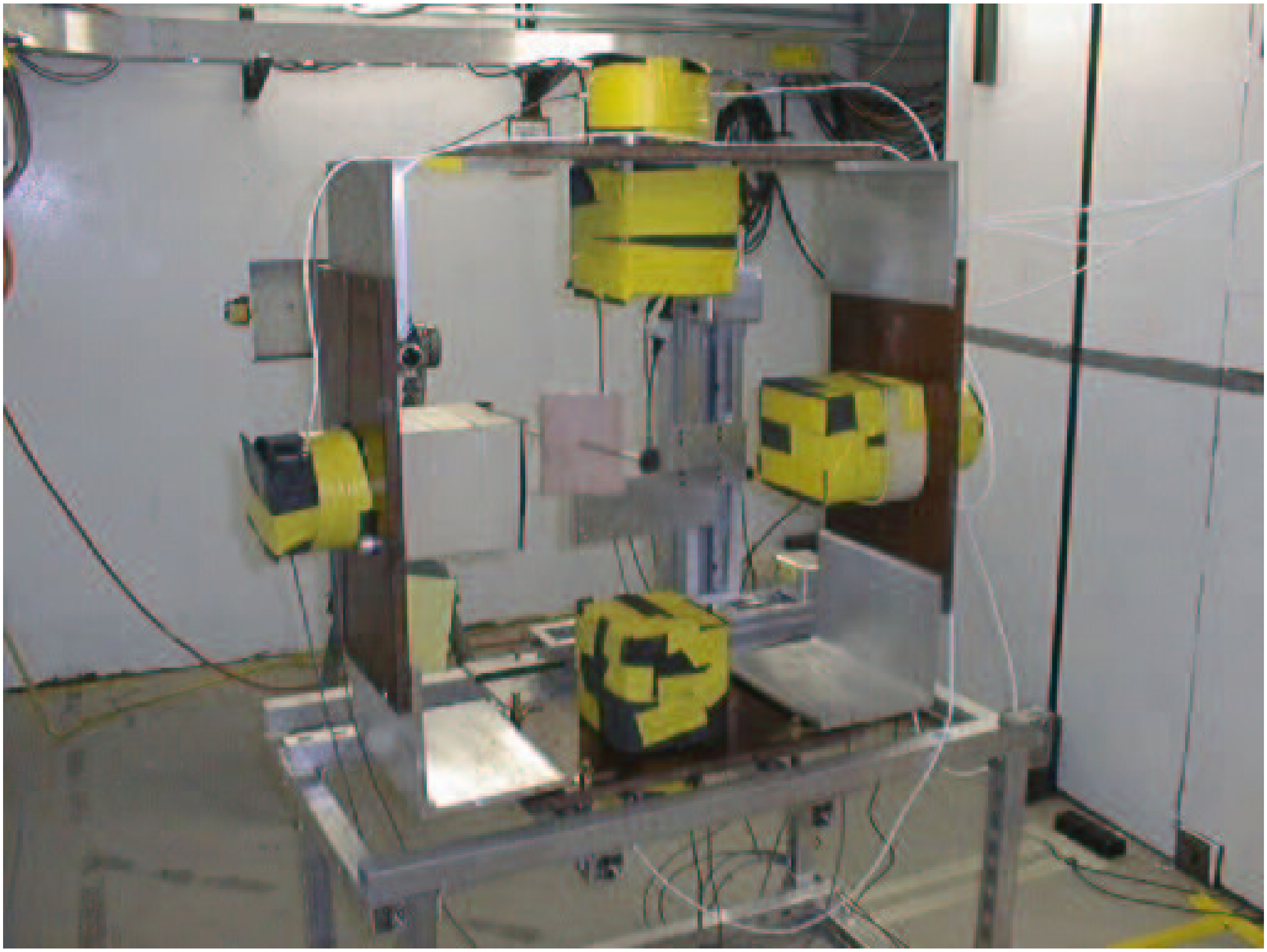


Parity-Conserving Asymmetries ($\times 10^{-6}$)

target	raw asymmetry	A_γ^{PC}
^{35}Cl	2.1 ± 2.1	-6.9 ± 6.9
^{113}Cd	1.6 ± 1.5	-4.7 ± 4.6
^{139}La	0.2 ± 2.3	-1.8 ± 7.1

Clever Method

Tested Fall 2001.

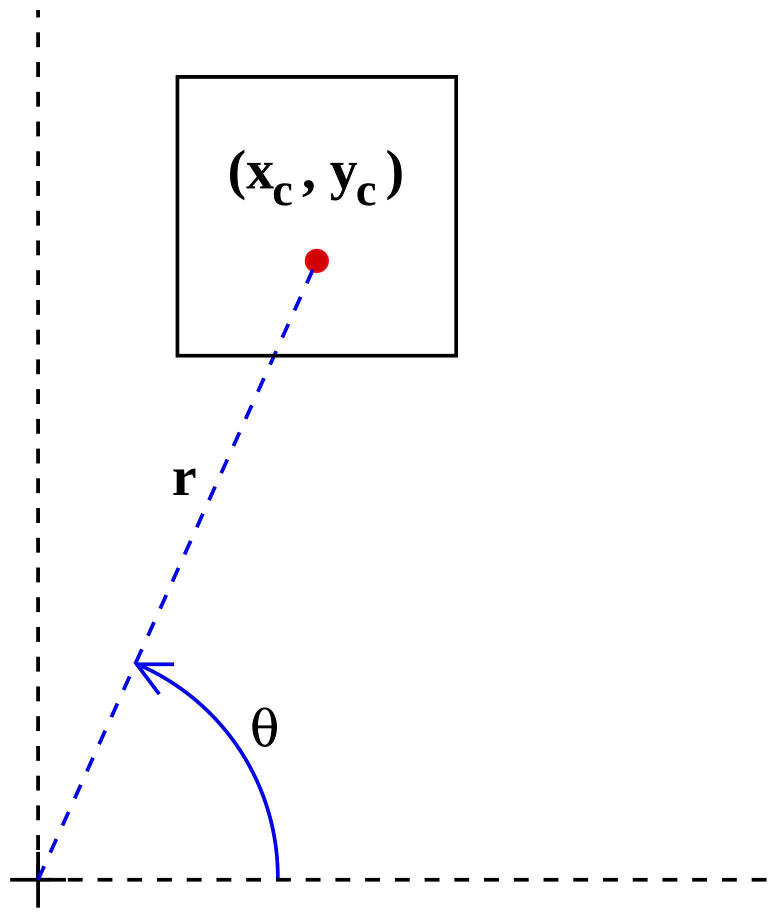


Place a small target which produces γ's upon neutron capture (B_4C or Cd metal) in the center of the array.

Scan the target x-y, and from the change in γ rates in the detectors, deduce (r, θ) for the effective center of each crystal.

Clever Method

(continued)



Scan ± 1 cm each direction. Detectors at $r \approx 30$ cm.

As the target moves x-y, detector rates change. First approximation, rate $\sim 1/r^2$ (solid angle).

Y_0: γ yield in detector at $(x, y) = (0, 0)$.

$$Y(x,y) = Y_0 \, \frac{x_c^2 + y_c^2}{(x_c - x)^2 + (y_c - y)^2}$$

Clever Method

(continued)

Measure Y_0, dY/dx and dY/dy at $(0,0)$.
Extract x_c, y_c, and thus r, θ:

$$r = \frac{2\ Y_0}{\sqrt{(dY/dx)^2 + (dY/dy)^2}}$$

$$\theta = \arctan \frac{dY/dy}{dY/dx}$$

Need tan(θ) uncertainty of $\sim 5\%$, $\sigma_Y \sim 0.2\%$, for 20 mrad precision.

Beam not sufficiently uniform.

(Would expect uniform beam from the guide, but it varies by 10% per cm. New FP12 guide should be better.)

Brute Force Method

Place entire detector assembly ($\sim$ 1000 kg) on stand with a few cm of x-y translation.

Use either small target or the full LH_2 target (20 ℓ) as a stationary γ source.

Beam monitors will determine incident n flux to 0.1% per pulse.

Alignment of x-y translation axes to B field axis is then the largest source of uncertainty.

This method is preferred to the previous ones in that regular in situ measurements are possible.

Stand is being engineered at TRIUMF.

Summary

Beginning in 2003, NPDGamma will make a precise measurement of the directional asymmetry A_γ in $\overrightarrow{\mathbf{n}} + \mathbf{p} \rightarrow \mathbf{d} + \gamma$.

To observe the small parity-violating asymmetry, the detector locations must be known to 20 mrad.

Elegant and clever methods for alignment not possible, making necessary translation of the entire detector assembly.

NPDGamma data taken in 2003 should equal the existing statistical precision on measurements of the PV meson-nucleon coupling H_π^1.